Pediatric Shoulder Arthroscopy is Effective and Most Commonly Indicated for Instability, Obstetric Brachial Plexus Palsy, and Partial Rotator Cuff Tears

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Purpose: The purpose of this review was to systematically evaluate the literature on pediatric shoulder arthroscopy and outline its indications, outcomes, and complications. **Methods:** This systematic review was carried out in accordance with PRISMA guidelines. PubMed, Cochrane Library, ScienceDirect, and OVID Medline were searched for studies reporting the indications, outcomes, or complications in patients undergoing shoulder arthroscopy under the age of 18 years. Reviews, case reports, and letters to the editor were excluded. Data extracted included surgical techniques, indications, preoperative and postoperative functional and radiographic outcomes, and complications. The methodological quality of included studies was evaluated using the Methodological Index for Non-Randomized Studies (MINORS) tool. **Results:** Eighteen studies, with a mean MINORS score of 11.4/16, were identified, including a total of 761 shoulders (754 patients). Weighted average age was 13.6 years (range, 0.83-18.8 years) with a mean follow-up time of 34.6 months (range, 6-115). As part of their inclusion criteria, 6 studies (230 patients) recruited patients with anterior shoulder instability and 3 studies recruited patients with posterior shoulder instability (80 patients). Other indications for shoulder arthroscopy included obstetric brachial plexus palsy (157 patients) and rotator cuff tears (30 patients). Studies reported a significant improvement in functional outcomes for arthroscopy indicated for shoulder instability and obstetric brachial plexus palsy. A significant improvement was also noted in radiographic outcomes and range of motion for obstetric brachial plexus palsy patients. The overall rate of complication ranged from 0% to 25%, with 2 studies reporting no complications. The most common complication was recurrent instability (38 patients of 228 [16.7%]). Fourteen of the 38 patients (36.8%) underwent reoperation. **Conclusion:** Among pediatric patients, shoulder arthroscopy was indicated most commonly for instability, followed by brachial plexus birth palsy, and partial rotator cuff tears. Its use resulted in good clinical and radiographic outcomes with limited complications. **Level of Evidence:** Systematic review of Level II to IV studies.

Shoulder arthroscopy is one of the most frequently performed orthopaedic procedures.[1] In adults, arthroscopic techniques are commonly used in the operative treatment of rotator cuff repair, adhesive capsulitis, proximal biceps pathology, labral tears, and instability.[1,2] The development of smaller arthroscopes and advances in technique have resulted in expanding indications for shoulder arthroscopy in pediatric and adolescent patients. Despite this increased use, indications for pediatric shoulder arthroscopy remain unclear. Although most commonly performed for recurrent instability,[3] pediatric shoulder arthroscopy has also been reported for the management of infection, brachial plexus palsy, traumatic dislocation, and rotator cuff repair.[3,4]

Pediatric arthroscopy theoretically carries a higher risk of complication because of the relatively smaller

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joint space available compared to adult procedures, increasing the likelihood of damage to adjacent structures.[4] In adults, the risk of complication after shoulder arthroscopy is similar to or lower than that of corresponding open procedures,[5,6] with an overall 30-day complication rate of less than 1%.[7] Although the issue of a smaller working field in pediatric patients has been minimized by more appropriately sized arthroscopy equipment, few studies have quantified the complication rate of pediatric shoulder arthroscopy. Individual studies report inconsistent complication rates and clinical outcomes for pediatric shoulder arthroscopy compared to the equivalent adult procedure but remain limited by small sample sizes.[4,8-12]

The purpose of this review was to systematically evaluate the literature on pediatric shoulder arthroscopy and outline its indications, outcomes, and complications. We hypothesize that pediatric shoulder arthroscopy is a safe and efficacious procedure.

Methods

Systematic Search

This review was performed in accordance with PRISMA guidelines using the Cochrane handbook. The research question, eligibility criteria, and search terms were established a priori. Electronic databases, including PubMed, Cochrane Library, ScienceDirect, and OVID Medline were searched on May 5, 2022, using the keywords and Boolean operators "pediatric," OR "skeletally immature," OR "child," OR "adolescent," AND "shoulder," AND "arthroscopy." Searches were done with no restriction for date, language, or publication format by 2 independent reviewers. References cited in the eligible studies were also scanned to find relevant studies not identified in the database search.

Inclusion/Exclusion Criteria

The research question and inclusion criteria were established a priori. Studies were considered eligible for inclusion if they met the following criteria: (1) patients were < 18 years old; (2) patients underwent shoulder arthroscopy; (3) indications, complications, or functional outcomes were reported. Studies were excluded if they (1) were non-full text studies such as conference abstracts; (2) were reviews, systematic reviews, case reports, or letters to the editor; (3) did not report a level of evidence; or (4) included patients > 18 years old. Nonrandomized studies were included because of the lack of randomized trials published to date investigating the use of shoulder arthroscopy in pediatric patients.

Two independent authors (N.I. and D.M.P.) screened abstracts of potentially eligible studies and subsequently performed a full-text review of remaining studies to determine final inclusion. Consensus was reached between reviewers through discussion. If no consensus was reached between the 2 reviewers, a senior author (S.Y.S.) was consulted. Search results were uploaded to Covidence (Veritas Health Innovation, Melbourne, Australia).

Quality Assessment

The methodological quality of included studies was evaluated using the Methodological Index for Non-Randomized Studies (MINORS) tool. The MINORS tool consists of 8 items for noncomparative studies that are rated as 0 (not reported), 1 (reported but inadequate), and 2 (reported and adequate) for a maximum score of 16.[13] For the purposes of this study, all studies were evaluated in a noncomparative context. Studies were categorized as very low quality (0-4), low quality (5-7), fair quality (8-12), and high quality (>13) based on previous systematic reviews.[14] Level of evidence was assigned according to the classification system by Poehling and Jenkins.[15]

Data Extraction

Standard data extraction forms were used within Covidence. Data abstracted included authors, year of publication, study design, level of evidence, sample size, sex ratio, mean age, mean follow-up duration, surgical techniques, surgical indications, preoperative and postoperative clinical functional and radiographic outcomes, and complications. Pain scores reported as visual assessment scale or numerical rating scales (NRS) were standardized to a 0-10 scale. WebPlotDigitizer was used to extract data from graphs.[16] Unreported standard deviations were calculated using the *P* value as described by the Cochrane Handbook for Systematic Reviews of Interventions.[17]

Assessment of Agreement

Kappa statistic (κ) was calculated for the full-text screening. A $\kappa < 0.21$ was considered slight agreement, κ of 0.21-0.60 was moderate agreement, and $\kappa > 0.61$ was substantial agreement.[18]

Statistical analysis

The results of this review are presented in a descriptive summary because of nonuniform reporting of surgical indications, outcomes, and complications. Descriptive statistics were calculated using Microsoft Excel (version 16.43, Microsoft Corporation, Redmond, WA). The 95% confidence intervals were calculated using the adjusted Wald technique.

Results

Search Results

The initial search of the online databases resulted in 3053 total studies. After removal of non-full text studies and duplicates, 35 full-text studies were obtained for screening. A systematic screening and assessment of eligibility identified 16 full-text articles that satisfied inclusion and exclusion criteria. Manual screening of the citations of included full-text articles identified an updated version of a previously identified article. An additional 2 studies were identified through a manual Google Scholar search. A total of 18 full-text articles were included in the final analysis (Fig 1). The reviewers reached substantial agreement at the full-text screening stage (κ =1.00).

Study Quality

Two studies were of Level II evidence (11.1%), 3 of Level III (16.7%), and 13 of Level IV (72.2%). The mean MINORS score was 11.4 (range, 10-15) out of a possible 16 points. Seventeen of the 18 (94.4%) studies were of fair quality, and 1 (5.6%) was of high quality.

Study Characteristics

Study demographics are outlined in Table 1. Included studies involved a total of 761 shoulders in 754 patients. The weighted average age of included patients was 13.6 years (range, 0.83-18.8 years). Sixteen of the 18 included studies reported the percentage of male and female patients, with majority male patients in 11 studies, majority female patients in 4 studies, and 1 study reporting an equal distribution. Mean follow-up reported by 16 studies was 34.6 months (range, 6-115). Two studies reported minimum follow-up rather than mean follow-up. As part of their inclusion criteria, 6 studies exclusively recruited patients with obstetric brachial plexus palsy (157 patients), 6 studies exclusively recruited patients with anterior shoulder instability (230 patients), 3 studies exclusively recruited patients with posterior shoulder instability (80 patients), 2 studies exclusively recruited athletes with traumatic sports-related instability (122 patients), 1 study exclusively recruited patients with partial rotator cuff tears (30 patients), 1 study recruited all pediatric patients undergoing arthroscopic stabilization for instability (57 patients), and 1 study recruited all pediatric patients undergoing shoulder arthroscopy (200 patients).

Patient positioning was reported by 14 of 18 studies. Ten studies reported use of the lateral decubitus position[9,11,19-26] and 2 studies reported use of the beach chair position.[27,28] One study reported use of both positioning techniques, with 72% of patients in the lateral decubitus position and 28% in the beach chair position.[8] Five studies specified the size of the arthroscope used. The most common was 2.7 mm in 5 studies,[19-23] followed by 3.2 mm in 1 study.[21] Eleven studies in total reported the arthroscopic portals used.[10,11,19-25,28,29]

Indications and Procedures

The most common indication for pediatric shoulder arthroscopy was instability (566/761 [74.4%]),[8-12,24,25,27-30] followed by obstetric brachial plexus palsy (157/761 [20.6%])[19-23,31] and partial rotator cuff tear (30/761 [3.9%]) (Table 2).[26] Among patients with instability, anterior instability was more common (466/566 [82.3%])[8,9,11,12,25,27,28,30] than posterior instability (100/566 [17.7%]).[8,10,24,29]

Surgical treatment for instability consisted of capsulolabral repair with or without SLAP or humeral avulsion of the glenohumeral ligament repair.[9-12,24,25,27-29] The 7 studies on brachial plexus birth palsy reported release of structures including the anterior capsule, superior glenohumeral ligament, middle glenohumeral ligament, inferior glenohumeral ligament, coracohumeral ligament, subscapularis tendon, and/or rotator interval tissue.[19-23,31] Four studies included

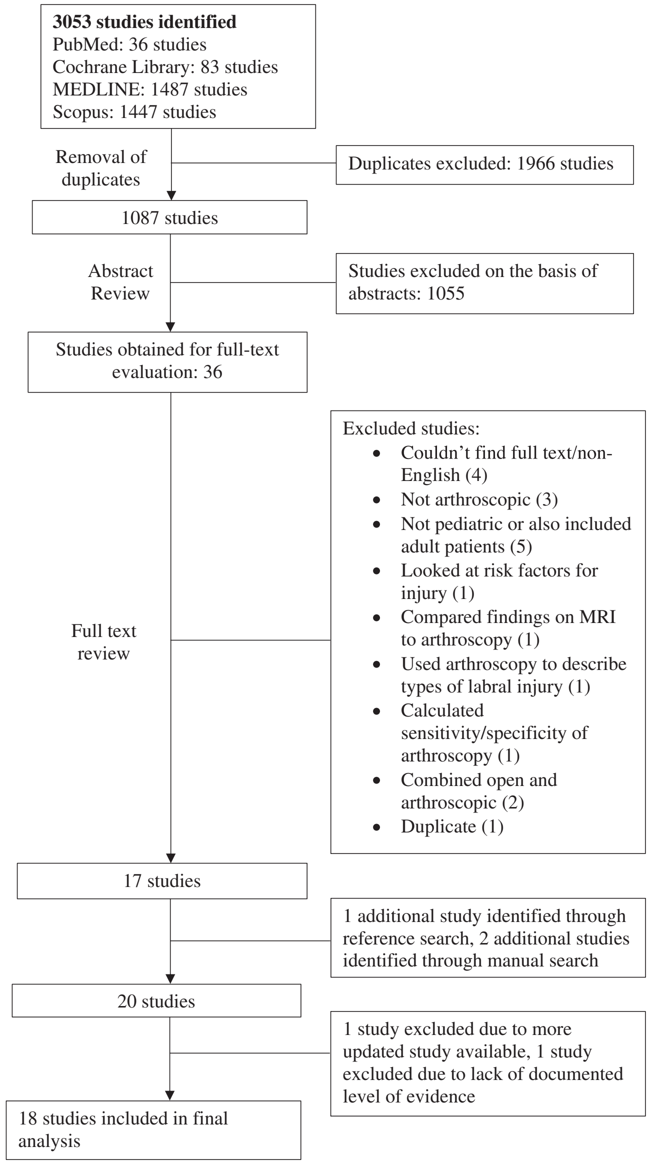

Fig 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram.

Table 1. Study Characteristics

Study	Level of Evidence	MINORS score	No. of shoulders (patients)	Male/Female	Follow-up Time (mo)	Mean age (yr)
Abid et al.[31]	IV	11/16	6 (6)	NR	60 (range, 42-72)	1.9 (range, 1.2-4.5)
Breton et al.[19]	IV	10/16	18 (18)	27.8% male, 72.2% female	54 (range, 12-84)	4.17 (range, 1-11)
Kozin et al.[20]	IV	11/16	44 (44)	36.4% male, 63.6% female	12 ± 3.6	2.7 (range, 0.9-8.4)
Mehlman et al.[21]	IV	12/16	50 (50)	46% male, 54% female	30 (range, 24-65)	5.1 (range, 0.83-11.8)
Pearl et al.[22]	IV	11/16	33 (33)	45.5% male, 54.5% female	Minimum 24	3.7 (range, 0.83-12)
Armangil et al.[23]	IV	11/16	6 (6)	66.7% male, 33.3% female	Minimum 12 months	5.1 (range, 3-8)
Asturias et al.[29]	IV	11/16	48 (48)	52.1% male, 47.9% female	45 (range, 15-76.8)	16.5 (range, 12.4-17.9)
Castagna et al.[9]	IV	11/16	65 (65)	67.7% male, 32.3% female	63 (range, 51 to 92)	16 (range, 13-18)
Greiwe et al.[24]	IV	12/16	10 (10)	50% male, 50% female	31 ± 6.5	16.2 ± 2.33
Kramer et al.[25]	IV	12/16	36 (36)	NR	35.6 ± 13.8 (range, 12.3-69.9)	16.03 ± 1.67
Kraus et al.[27]	II	12/16	5 (5)	85.7% male, 14.3% female	26 (range, 13-48)	12 (range, 11-15)
Nixon et al.[28]	IV	12/16	61 (57)	98% male, 2% female	22 (range, 3-69)	16.8 (range, 13-18)
Wooten et al.[10]	IV	12/16	25 (22)	86.3% male, 13.6% female	63 (range, 24-115)	17 (range, 14-17.9)
Gigis et al.[11]	II	10/16	38 (38)	63.1% male, 26.9% female	36	16.7 (range, 15-18)
Jones et al.[12]	III	10/16	16 (16)	56.7% male, 43.4% female	25.2	15.4 (range, 11-18)
Cheng et al.[30]	III	15/16	70 (70)	82.9% male, 17.1% female	64.6 ± 24.1 (minimum 24 mo)	16.1 (range, 15.4-16.8)
Eisner et al.[26]	III	11/16	30 (30)	71.7% male, 28.3% female	16.9 (range, 7-30)	15.8 (range, 8.8-18.8)
Edmonds et al.[8]	IV	12/16	200 (200)	73% male, 27% female	6	15.9 (range, 1-18)

MINORS, Methodological Index for Non-Randomized Studies.

brachial plexus palsy patients who underwent concomitant latissimus dorsi or teres major tendon transfer,[20-22,31] whereas 1 study excluded patients who underwent tendon transfer.[19]

Outcomes

Shoulder Instability

Range of motion (ROM) was reported by 3 studies (100 patients).[9,10,24] Two studies reported forward elevation, external rotation, and internal rotation (32 patients),[10,24] and 1 study reported forward flexion and external rotation with the arm at 90° of abduction (65 patients).[9] Mean forward elevation ranged from 163.6° to 172° before surgery and from 165.6° to 174° after surgery (32 patients).[10,24] External rotation ranged from 68.0° to 76° before surgery and from 65.8° to 72° after surgery (32 patients).[10,24] One study (10 patients) reported a decrease in internal rotation from a vertebral level of T5 before surgery to T6 after surgery,[24] whereas another (22 patients) contrarily reported an improvement of 1 level of internal rotation with patients improving from 14.6° before surgery to 15.7° after surgery.[10] No significant difference was found between preoperative and postoperative ROM (100 patients).[9,10,24]

Outcomes reported before and after surgery in 2 or more studies were the American Shoulder and Elbow Surgeons (ASES) score (2 studies, 75 patients)[9,24] and the Rowe score (2 studies, 103 patients).[9,11] Before surgery, the mean ASES scores ranged from 36.92 to 52.2 and mean Rowe scores ranged from 35.9 to 57.3. After surgery, the mean ASES ranged from 84.12 to 85.9 and mean Rowe scores ranged from 85 to 88.3. Both studies reporting mean ASES scores before and after surgery found a significant improvement, with an increase reported by Castagna et al.[9] from 36.92 ± 4.0 to 84.12 ± 25.4 and by Greiwe et al.[24] from 52.2 ± 18.7 to 85.9 ± 14.9. The improvement in ASES exceeded the minimal clinically important difference of 15.5.[32] Of the 2 studies reporting preoperative and postoperative Rowe score, Castagna et al.[9] was the only study to report a significant difference between preoperative and postoperative Rowe score with an improvement from 35.9 ± 4.1 to 85.0 ± 26.0, whereas Gigis et al.[11] did not report level of significance, although both studies met the minimal clinically important difference of 9.7.[33]

Average Single Assessment Numeric Evaluation score after surgery was reported by 3 studies (129 patients),[9,12,29] ranging from 78.58 to 91.8. Of these 3 studies, only one reported both preoperative and postoperative Single Assessment Numeric Evaluation scores and found a significant improvement from 46.15 ± 6.4 to 87.2 ± 23.7.[9] Two studies reported mean pain scores after surgery (32 patients),[10,24] ranging from 1.44 to 3.0. Of the two studies, Greiwe et al.[24] was the only one to report mean pain scores before and after surgery and found a significant decrease from 5.33 ± 3.50 to 1.44 ± 2.00.[24]

Participation in sports was reported by 9 studies (310 patients)[9-12,24,25,28-30] with the sport specified for 171 patients.[9,24,28,29] The most common sports were football/rugby (76 patients),[9,28,29] volleyball (14 patients),[9] tennis (13 patients),[9,24] soccer (11 patients),[9,24] swimming (10 patients),[9,24] basketball (7 patients),[9] water polo

Table 2. Indications for Shoulder Arthroscopy and Arthroscopic Technique

Study	No. of Shoulders (Patients)	Indication for Arthroscopy (n = Shoulders)	Surgical Intervention(s) Used
Abid et al.[31]	6 (6)	6 IR contracture with passive ER at elbow < 0° secondary to obstetric brachial plexus birth palsy after stretching exercises	6 Arthroscopic release of the capsule, SGHL, MGHL, and CHL with or without latissimus tendon transfer
Breton et al.[19]	18 (18)	18 Passive ER at elbow < 10° secondary to obstetric brachial plexus palsy	Arthroscopic release of the anterior capsule, MGHL and/or the SGHL, rotator interval, CHL, and the IGHL, subscapularis tenotomy
Kozin et al.[20]	44 (44)	44 IR contracture secondary to obstetric brachial plexus palsy	28 arthroscopic release of the SGHL, MGHL, IGHL, upper ½ to $^2/_3$ of subscapularis, partial subscapularis tenotomy 16 arthroscopic capsular release, partial subscapularis tenotomy, and concomitant tendon transfers (latissimus dorsi and teres major)
Mehlman et al.[21]	50 (50)	50 IR contracture secondary to obstetric brachial plexus palsy	50 arthroscopic Server L'Episcopo procedures 36 arthroscopic release of subscapularis tendon and variable amount of anterior capsule with open latissimus dorsi tendon transfer 14 isolated arthroscopic release of subscapularis tendon and variable amount of anterior capsule
Pearl et al.[22]	33 (33)	33 IR contracture with ER at elbow < 0° secondary to obstetric brachial plexus birth palsy after 2-3 months of stretching exercises	19 isolated release of MGHL, anterior part of IGHL, subscapularis tenotomy, and/or rotator interval tissue 4 of these patients underwent late latissimus dorsi transfer due to recurrence of internal contracture 14 arthroscopic release of MGHL, anterior part of IGHL, subscapularis tenotomy, and/or rotator interval tissue with latissimus dorsi transfer
Armangil et al.[23]	6 (6)	6 IR contracture secondary to obstetric brachial plexus palsy after 2 months of unsatisfactory conservative management	6 Arthroscopic subscapular tenotomy and release of anterior capsular ligaments at attachment to glenoid labrum, release of tissues from the rotator interval to the coracoid process
Asturias et al.[29]	48 (48)	48 posterior shoulder instability that failed to improve after 6 weeks of PT • 11 acute trauma • 20 recurrent instability • 17 apparent atraumatic pain	48 Arthroscopic capsulolabral reconstruction
Castagna et al.[9]	65 (65)	65 recurrent sports-related traumatic anterior shoulder instability	65 Arthroscopic stabilization procedures • 41 Bankart repairs • 19 ALPSA repairs • 5 capsulolabral retensioning procedures
Greiwe et al.[24]	10 (10)	10 voluntary recurrent posterior instability with multidirectional instability after failed nonoperative treatment • 1 isolated anterior and inferior • 5 isolated posterior and inferior • 4 combined anterior, posterior and inferiorConcomitant injuries: • 3 SLAP tears • 1 partial thickness rotator cuff tear • 1 glenoid chondral injury	5 Capsular plications 5 SLAP or labral repair with associated capsulorrhaphy
Kraus et al.[27]	5 (5)	5 recurrent traumatic anterior shoulder instability	5 arthroscopic Bankart repairs
Kramer et al.[25]	36 (36)	36 traumatic anterior shoulder instability • 33 recurrent instability • 3 first-time dislocation	36 arthroscopic Bankart repairs, which included 6 remplissages for "off-track" Hill-Sachs lesions, 5 concomitant posterior labral repairs, and 2 SLAP repairs
Nixon et al.[28]	61 (57)	61 traumatic sports-related recurrent anterior shoulder instability	61 arthroscopic stabilization procedures • 51 Bankart repairs, which included 8 ALPSA repairs, 1 HAGL repair, and 13 bony Bankart repairs • 10 posterior labral repairs

(continued)

Table 2. Continued

Study	No. of Shoulders (Patients)	Indication for Arthroscopy (n = Shoulders)	Surgical Intervention(s) Used
Wooten et al.[10]	25 (22)	25 recurrent posterior shoulder instability	25 arthroscopic posterior labral repair • 19 capsular shift • 6 without capsular shift
Gigis et al.[11]	38 (38)	38 first traumatic anterior shoulder instability	38 Arthroscopic Bankart repairs
Jones et al.[12]	16 (16)	16 traumatic anterior shoulder dislocation	16 Arthroscopic Bankart repairs
Cheng et al.[30]	70 (70)	70 anterior shoulder instability	70 Arthroscopic Bankart repairs
Eisner et al.[26]	30 (30)	30 partial rotator cuff tears, PASTA after failed 6-week course of PT	30 Arthroscopic debridements • 14 posterior labral repair • 7 anterior labral repair
Edmonds et al.[8]	200 (200)	NR	175 Anterior labrum or SLAP repair 17 Posterior labral repair 8 PASTA Debridement, subacromial decompression, loose body removal, or distal clavicle resection

NR, not reported; PT, physical therapy; IR, internal rotation; ER, external rotation; HAGL, humeral avulsion of the glenohumeral ligament; ALPSA, anterior labroligamentous periosteal sleeve avulsion; PASTA, partial articular sided tendon avulsions; SGHL, superior glenohumeral ligament; MGHL, middle glenohumeral ligament; CHL, coracohumeral ligament; IGHL, inferior glenohumeral ligament.

(5 patients),[9] snow sports (2 patients),[28] lacrosse (1 patient),[24] gymnastics (1 patient),[24] baseball (1 patient),[24] wrestling (1 patient),[24] and surfing (1 patient).[24] Return to sport was reported by 5 studies (207 patients)[9-11,25,28] and ranged from 81% to 92.6% (Fig 2). The percentage of patients who returned to full pre-injury level of sport ranged from 61% to 81%. The proportion of patients who experienced repeat instability after arthroscopic stabilization was reported by 5 studies (177 patients)[9-12,25] and ranged from 11% to 25% (Fig 3).

Brachial Plexus Birth Palsy

Two studies (94 patients)[20,21] reported the mean Mallet functional score preoperatively and postoperatively, which ranged from 12.6 to 12.7 and from 16.3 to 17.1, respectively. Both studies evaluating mean Mallet score reported a significant improvement, with scores from Kozin et al.[20] improving from 12.7 ± 1.6 to 17.1 ± 1.4 and scores from Mehlman et al.[21] improving from 12.6 to 16.3.

Reported radiographic outcomes included degree of glenoid retroversion, percentage of humeral head anterior to middle of glenoid fossa (PHHA), and the Glenoid Deformity score. Four studies (118 patients)[19-21,31] reported an improvement in the degree of glenoid retroversion, which ranged from −25° to −34° before surgery and from −12.81° to −19° after surgery (Fig 4). Of these 4 studies, 3 studies (100 patients)[20,21,31] reported that this increase was significant, whereas 1 study did not report the level of significance.[20] PHHA before and after surgery was reported by 4 studies (118 patients)[19-21,31] and ranged from 19% to 31% before surgery and from 33% to 41% after surgery (Fig 5). Two (94 patients)[20,21] out of these 4 studies reported a significant improvement in PHHA. Two studies (94 patients)[20,21] reported mean preoperative and postoperative glenoid deformity score, which ranged from 2.8 to 2.9 before surgery and improved to 1.9 after surgery. Both studies reported this improvement was significant, with Mehlman et al.[21] reporting a decrease from 2.8 to 1.9 and Kozin et al.[20] from 2.9 ± 1.0 to 1.9 ± 0.4.

The most commonly reported ROM outcome before and after surgery was passive external rotation (3 studies, 68 patients),[19,20,31] which significantly improved from −1° to −26° preoperatively and from 47° to 58° after surgery. Preoperative and postoperative internal rotation (IR) using the Mallet score was assessed by 2 studies (24 patients)[19,31] and ranged from 2.3 to 3.2 out of 5 before surgery and from 2.1 to 2.2 after surgery. Abid et al.[31] reported an IR of 2.3/5 before surgery and 2.2/5 after surgery, which was not statistically significant. Breton et al.[19] reported preoperative IR to be 3.2/5 and postoperative IR to be 2.1/5 but did not report level of significance.

Complications

Complications were described by 9 studies (437 patients) (Table 3).[8-12,23,25,29-31] The overall rate of complications ranged from 0% to 25%. Of the 9 studies discussing complications, 2 studies reported no complications after arthroscopy.[23,31] Complications included recurrent instability (38 patients), allergic reaction (3 patients), transient hand dysesthesias (2 patients), postoperative headache (2 patients), tendinitis (2 patients), bronchitis (1 patient), syncope (1 patient), transient hypotension (1 patient), uvula swelling (1 patient), broken pain pump catheter (1 patient),

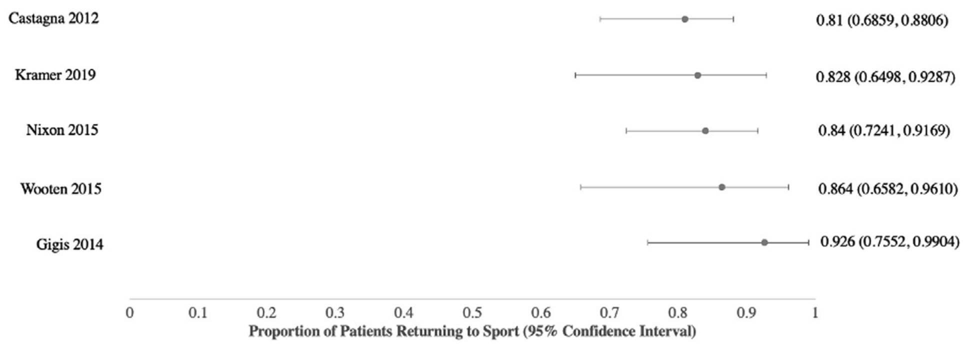

Fig 2. Forest plot of the rate of return to sport for shoulder instability patients ± 95% confidence interval.

laceration of the cephalic vein (1 patient), and readmission for pain control (1 patient). Further surgical intervention was required in 14 of these patients, with recurrent instability being the most common indication (14 patients). The rate of reoperation for recurrent instability patients was 36.8% (14/38).

Discussion

The results of this review demonstrate shoulder arthroscopy is an effective procedure in patients under the age of 18 for a number of indications, most commonly instability, followed by obstetric brachial plexus birth palsy, and partial rotator cuff tears. Among patients undergoing arthroscopy for shoulder instability, there was a significant improvement in ASES, Rowe, and pain scores after surgery, with a high percentage of athletes returning to sport. Mallet functional score, glenoid retroversion, PHHA, glenoid deformity score, and external rotation significantly improved for patients after arthroscopy for obstetric brachial plexus palsy. Although complications of shoulder arthroscopy were limited, postoperative recurrent instability was the most common complication and may occur in up to 25% of patients. These findings are consistent with the prior hypothesis that pediatric shoulder arthroscopy is safe and efficacious.

Shoulder arthroscopy in adult patients may be performed for diagnostic purposes or for the treatment of degenerative or traumatic pathologies, including rotator cuff tears, labral tears, and instability.[1,2] In a retrospective analysis of the National Survey of Ambulatory Surgery, Jain et al.[1] determined shoulder arthroscopy was most commonly performed for instability or SLAP lesions, followed by arthroscopic rotator cuff repair in patients between the ages of 15 to 44. Indications for shoulder arthroscopy in pediatric patients are more frequently the result of traumatic events, particularly during birth or sports participation. Similar to what was reported by Jain et al.[1] for adult patients, this analysis found that pediatric patients were more likely to undergo shoulder arthroscopy for instability than rotator cuff repair. Pediatric patients also underwent shoulder arthroscopy for obstetric brachial plexus birth palsy, usually corrected during the first few years of life and rarely extending to adulthood.[34]

In this study, variability in reported outcome scores and follow-up duration of the current literature made it difficult to draw specific conclusions about the clinical impact of shoulder arthroscopy in pediatric patients. An additional barrier to determining the outcomes and cause of the complication rate of up to 25% is the variability of surgical approach, particularly for instability patients. Further limiting comparison

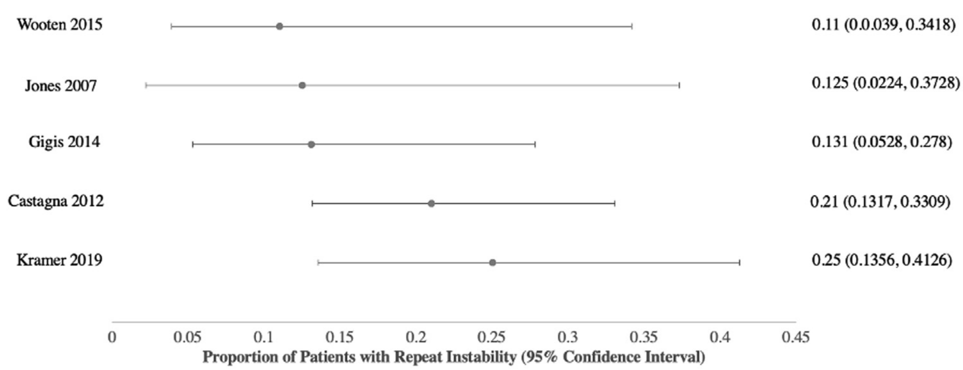

Fig 3. Forest plot of proportion of patients experiencing repeat instability after arthroscopic stabilization ± 95% confidence interval.

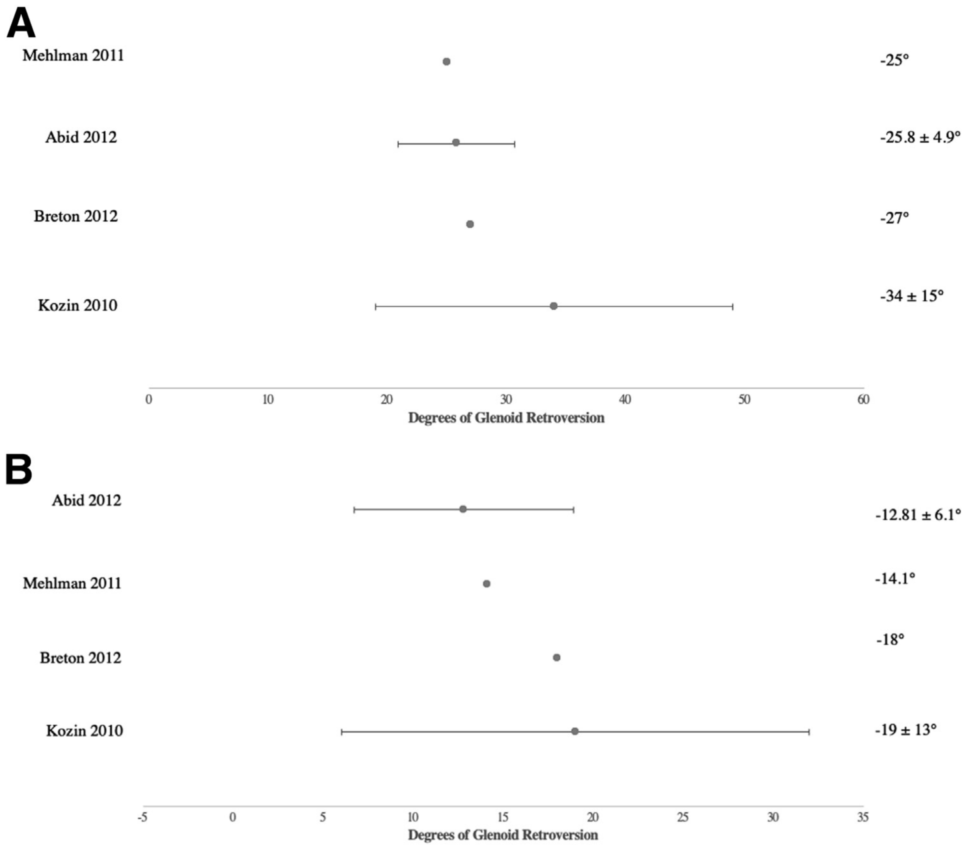

Fig 4. Forest plot of mean ± standard deviation (where available) of the degree of glenoid retroversion in obstetric brachial plexus palsy patients (A) before and (B) after operation.

between outcomes of pediatric and adult shoulder arthroscopy is the lack of available literature examining long-term outcomes for shoulder arthroscopy overall because of the relative novelty of the technique.[35] Functional outcomes for pediatric patients after shoulder arthroscopy that could be analyzed largely improved in this study. Although ASES and pain scores of pediatric patients undergoing arthroscopy for instability significantly improved after surgery, ROM remained relatively consistent before and after arthroscopy, similar to outcomes reported for adult patients.[36-39] The majority of instability patients in this study returned to sport after surgery, at a similar rate to that previously reported of all patients undergoing arthroscopic procedures for instability.[39,40] Clinical outcomes for surgical repair of rotator cuff tears in pediatric patients have been reported to be excellent, but these studies have not independently reported outcomes for open and arthroscopic repair.[41,42] Only one study included in this review, Eisner et al.,[26] evaluated clinical outcomes of partial-thickness rotator cuff tears treated with arthroscopic repair but did not obtain preoperative scores and was thus unable to quantify the clinical benefit of arthroscopic repair. Arthroscopy for obstetric brachial plexus birth palsy resulted in improved Mallet, glenoid retroversion, PHHA glenoid deformity score, and external rotation after surgery consistent with previous systematic reviews.[43,44]

Although clinical outcomes for pediatric shoulder arthroscopy are good, the risk of complications remains higher in pediatric patients than in adults and has previously been attributed to a smaller available joint space.[4-8] To reduce the rate of complications, more appropriately sized arthroscopy equipment has been developed[3] and is primarily used for younger pediatric patients. In adults, complications of shoulder arthroscopy are less frequently vascular or related to infection than neurologic.[2,46,47] Fortunately, neurologic injury, which may be to the brachial plexus, axillary, musculocutaneous, suprascapular, posterior auricular, hypoglossal, or peroneal nerves, are typically transient.[2,45,46] Patient positioning, specifically the beach-chair position, has also been implicated in a higher risk for stroke and blindness secondary to cerebral hypoperfusion.[2] For all patients undergoing shoulder arthroscopy, the risk of developing complications within the first 30 days after surgery is less than 1%,[7] but 3.8% of patients require revision surgery within 1 year.[47] In comparison, Edmonds et al.[8] determined the overall complication

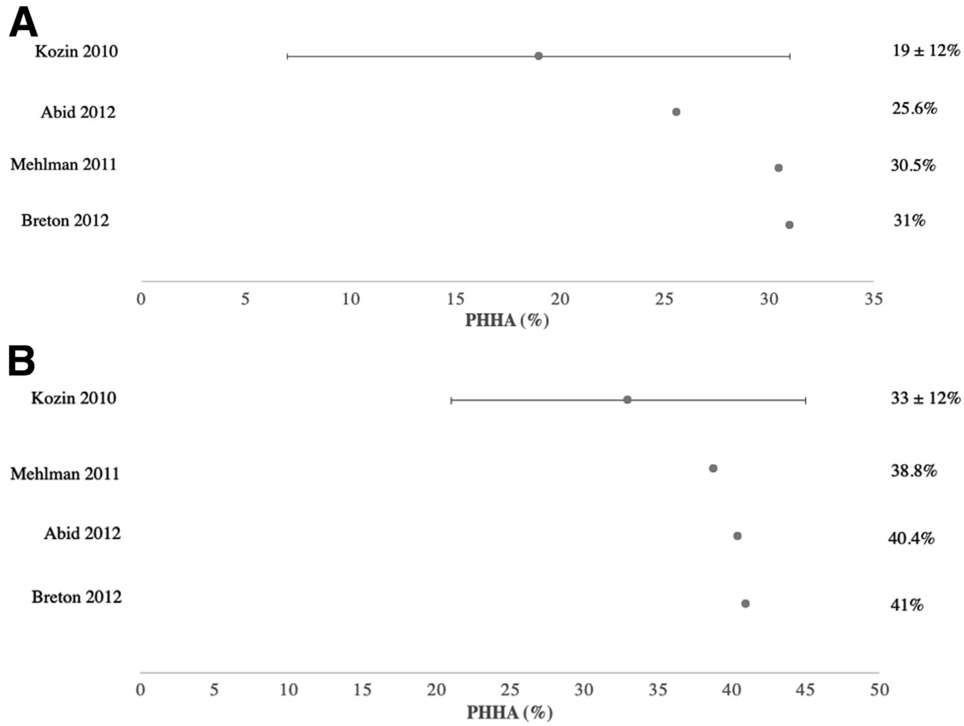

Fig 5. Forest plot of mean ± standard deviation (where available) of the mean percentage of humeral head anterior to middle of the glenoid fossa (PHHA) in obstetric brachial plexus palsy patients (A) before and (B) after operation.

rate for pediatric shoulder arthroscopy patients was 8.0% within the first six months, although no patients required revision surgery. As this study only included patients from 1997 to 2010, it is difficult to determine whether advances in surgical technique and equipment in the past decade have decreased the rate of complications. Among pediatric patients who had arthroscopy for instability, rates of recurrent instability ranged from 11% to 21%.[9-12] Rates of recurrent instability for adult patients are typically below 10%,[48,49] indicating a persistently elevated risk of complications for pediatric patients. Studies have suggested the higher rate of complications may be due to pediatric patients re-entering athletic activities too early or their lower adherence to physical therapy.[50,51] Notably, only one study reported assessment of postoperative multidirectional instability in pediatric patients, potentially artificially inflating the rate of recurrence.[12] However, more evidence is required to explore the safety of shoulder arthroscopy in pediatric patients.

The strengths of this systematic review are that this study is a comprehensive review of the indications for use of shoulder arthroscopy in the pediatric population, its functional, radiologic, and ROM outcomes, and characterizes the risk profile. This study will guide future studies because shoulder arthroscopy is safe and effective in pediatric patients.

Limitations

This systematic review is limited by the number and quality of studies available that met inclusion criteria. Although the majority of studies included in this review were of fair quality, there were no high-quality studies available. Furthermore, despite a thorough systematic search, there may have been studies that were not captured in the databases searched. Additionally, not all adult patient reported outcome scores have been validated in pediatric populations although shoulder and elbow scores such as the Pedi-ASES have been developed for use specifically in this population.[52] Moreover, heterogeneity in treatment approaches used, particularly when considering a high complication rate in the instability patient population, limits the ability to draw conclusions regarding the efficacy for this indication. Last, a number of studies were missing specific details regarding indications, procedure, arthroscope size, and patient positioning.

Conclusion

Among pediatric patients, shoulder arthroscopy was indicated most commonly for instability, followed by brachial plexus birth palsy, and partial rotator cuff tears. Its use resulted in good clinical and radiographic outcomes with limited complications.

Table 3. Clinical Outcomes and Complications Associated with Pediatric Shoulder Arthroscopy

Study	Preoperative Clinical Outcomes	Postoperative Clinical Outcomes	Preoperative Radiographic Outcomes	Postoperative Radiographic Outcomes	Preoperative ROM	Postoperative ROM	Complications
Abid et al.[31]	NR	NR	Glenoid version: −25.8° (range, −34° to − 22°) PHHA: 25.6% (range, 0%- 50%)	Glenoid version: −12.81° (range, −21 to − 4°) PHHA: 40.4% (range, 35%-50%)	Passive ER: −12.5° (range, −20° to 0°) IR with Mallet score: 2.3/5 Elevation and abduction: 56.6° (range, 50°-60°)	Passive ER: 50.8° (range, 45°to 50°) IR with Mallet score: 2.2/5 Elevation and Abduction: 156.71° (range, 140°-170°)	0 complications
Breton et al.[19]	NR	Modified Mallet functional score: 16/25 (range, 5 to 25)	% of concentric glenoids: 37% Glenoid retroversion on MRI: −27° (range, −56° to −9°) for injured shoulder, −6° (range, −14° to 1°) for healthy shoulder PHHA: 31% Humeral Head Hypoplasia: 54%	% of concentric glenoids: 61% Glenoid retroversion on MRI: −18° (range, −71° to −2°) for injured shoulder, −3° (range, −8° to 4°) for healthy shoulder PHHA: 41% Humeral Head Hypoplasia: 28%	Passive ER: − 1° (range, −20° to 10°) IR with Mallet score: 3.2/5	Passive ER: 58° (range, 5°-90°) IR with Mallet score: 2.1/5	NR
Kozin et al.[20]	Mallet functional score: 12.7 ± 1.6	Mallet functional score: 17.1 ± 1.4	PHHA: 19% ± 12% Retroversion: −34° ± 15° Glenoid Deformity score: 2.9 ± 1.0	PHHA: 33 ± 12% Retroversion: −19° ± 13° Glenoid Deformity score: 1.9 ± 0.4	Passive external rotation: −26° ± 20° Active elevation: 112° ± 28°	Passive external rotation: 47° ± 17° Active elevation: 130° ± 38°	NR
Mehlman et al.[21]	Mallet score: 12.6 (range, 5-18)	Mallet score: 16.3 (range, 12-23)	PHHA: 30.5% (range, 0%-54.4%) Glenoid retroversion: 25° (range, 7.7%-70.4°) Glenohumeral joint deformity score: 2.8 (range, 2-5)	PHHA: 38.8% (range, 0-54.0%) Glenoid retroversion: 14.1° (range, 0.4°-53.6°) Glenohumeral joint deformity score: 1.9 (range, 1-4)	NR	NR	NR

(continued)

Table 3. Continued

Study	Preoperative Clinical Outcomes	Postoperative Clinical Outcomes	Preoperative Radiographic Outcomes	Postoperative Radiographic Outcomes	Preoperative ROM	Postoperative ROM	Complications
Pearl et al.[22]	NR	NR	NR	NR	NR	Release only (excluding late latissimus transfer patients) Passive external rotation: 67° ± 22° Passive elevation: 5° ± 11° Active elevation: 12° ± 23° Passive ER at 90° abduction: 45° ± 18° Passive IR in 90° abduction: −37° ± 18°	NR
Armangil et al.[23]	NR	NR	NR	NR	Active ER: 7.5° ± 5.2° Mean active Abduction: 47.5°	Active ER: 41.7° ± 12.1° Mean active abduction: 80°	0 complications
Asturias et al.[29]	NR	SANE: 78.58 PASS: 79.28 QuickDASH: 17.15	NR	Glenoid retroversion: 8.89°	NR	NR	Failure rate, underwent revision 12.5% (n = 6)
Castagna et al.[9]	SANE: 46.15% (range, 20%-50%) Rowe: 35.9 (range, 30-50) ASES: 36.92 ± 4.0 (range, 30-48)	SANE: 87.23% (range, 30%-100%) Rowe: 85 (range, 30-100) ASES: 84.12 ± 25.4 (range, 30-100) Return-to-sport: 81%	NR	NR	Forward flexion: 180° ER with arm at 90° of abduction: 86°	Forward flexion: 180° ER with arm at 90° of abduction: 86°	Recurrent instability: 21% (n = 14)
Greiwe et al.[24]	VAS pain score: 5.33 ± 3.50 ASES: 52.2 ± 18.7 SST: 8.2 ± 3.2	VAS pain score: 1.44 ± 2.00 ASES: 85.9 ± 14.9 SST: 11.44 ± 1.01	NR	NR	Forward elevation: 172° ± 24° External rotation: 76° ± 12°	Forward elevation: 174 ± 10° External rotation: 72° ± 6°	NR

(continued)

Table 3. Continued

Study	Preoperative Clinical Outcomes	Postoperative Clinical Outcomes	Preoperative Radiographic Outcomes	Postoperative Radiographic Outcomes	Preoperative ROM	Postoperative ROM	Complications
Kraus et al.[27]	NR	Constant score: 92 (range, 87-98) No instability with apprehension test, sulcus sign Laxity: Anterior/ posterior translation grade 0 Rowe score: range, 95-100	NR	NR	NR	NR	NR
Kramer et al.[25]	NR	8.3% reported feelings of apprehension at final follow-up (n = 3) 82.8% return-to-sport (n = 24)	NR	NR	NR	NR	25% recurrent instability (n = 9)
Nixon et al.[28]	NR	Return-to-sport:61% full pre-injury, 23% decreased level of play Oxford Instability score: 26.8 ± 12.9	NR	NR	NR	NR	NR
Wooten et al.[10]	NR	ASES: 74.3 ± 20 (range, 20-100) Subjective stability score: 3.0 (range, 0-6) Subjective pain score: 3.0 (range, 0-9) Marx activity score: 14.8 ± 3.2 Return to sport: 86.4%	NR	NR	Active elevation: 163.6° External rotation: 68.0° Internal rotation: 14.6°	Active elevation: 165.6° External rotation: 65.8° Internal rotation: 15.7°	Recurrent traumatic posterior subluxation (11%) (n = 2)
Gigis et al.[11]	Rowe score: 57.3	Rowe score: 12 month: 85.7 24 month: 87.4 36 month: 88.3 Return to sport: 92.6%	NR	NR	NR	NR	Recurrence of instability (13.1%) (n = 5)
Jones et al.[12]	NR	SANE: 91.8 (range, 80-100)	NR	NR	NR	NR	Recurrent Instability (12.5%) (n = 2)

(continued)

Table 3. Continued

Study	Preoperative Clinical Outcomes	Postoperative Clinical Outcomes	Preoperative Radiographic Outcomes	Postoperative Radiographic Outcomes	Preoperative ROM	Postoperative ROM	Complications
Cheng et al.[30]	NR	NR	Glenoid bone loss: 2.43mm (range, 0.8-4.6) Glenoid retroversion: 6.0° (range, 3.9-7.9) Hill Sachs lesion size: 13.46 mm (range, 10.3-15.6)	NR	NR	NR	NR
Eisner et al.[26]	NR	SANE: 80.6 ± 17.1 fQuickDASH: 8.1 ± 11.1 QuickDASH sports module: 19.5 ± 24.3	NR	NR	NR	NR	NR
Edmonds et al.[8]	NR	NR	NR	NR	NR	NR	16 total complications (8.0%) Major complications (2.5%): 2 tendinitis/bursitis, 1 broken pain pump catheter, 1 readmission for pain control, 1 laceration of cephalic vein Minor complications (5.5%): 3 allergic reactions, 2 transient hand dysesthesias, 2 postoperative headaches, 1 bronchitis, 1 syncope, 1 transient hypotension, 1 uvula swelling

ER, external rotation; IR, internal rotation; PHHA, Percentage of humeral head anterior to middle of glenoid fossa; GH, glenohumeral; VAS, visual analog score; ASES, American Shoulder and Elbow Surgeons score; PASS, Pediatric and Adolescent Shoulder Survey; SANE, Single Assessment Numeric Evaluation; QuickDASH, Quick Disabilities of the Arm, Shoulder, and Hand score; NR, not reported; Recurrent instability, repeat dislocation and/or subluxation events.

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